Threshold raw retrieved contrast in coronagraphs is limited by internal polarization

Completed Technology Project (2017 - 2019)

Project Introduction

The objective of this work is to provide the exoplanet program with an accurate model of the coronagraph complex point spread function, methods to correct chromatic aberration in the presence of polarization aberrations, device requirements to minimize and compensate for these aberrations at levels needed for exoplanet coronagraphy, and exoplanet retrieval algorithms in the presence of polarizaiton aberrations. Currently, space based coronagraphs are designed and performance analyzed using scalar wave aberration theory. Breckinridge, Lam & Chipman (2015) PASP 127: 445-468 and Breckinridge & Oppenheimer (2004) ApJ 600: 1091-1098 showed that astronomical telescopes designed for exoplanet and precision astrometric science require polarization or vector-wave analysis. Internal instrument polarization limits both threshold raw contrast and measurements of the vector wave properties of the electromagnetic radiation from stars, exoplanets, gas and dust. The threshold raw contrast obtained using only scalar wave theory is much more optimistic than that obtained using the more hardware-realistic vector wave theory. Internal polarization reduces system contrast, increases scattered light, alters radiometric measurements, distorts diffraction-limited star images and reduces signal-to-noise ratio. For example, a vector-wave analysis shows that the WFIRST-CGI instrument will have a threshold raw contrast of 10-7 not the 10-8 forecasted using the scalar wave analysis given in the WFIRST-CGI 2015 report. The physical nature of the complex point spread function determines the exoplanet scientific yield of coronagraphs. We propose to use the Polaris-M polarization aberration ray-tracing software developed at the College of Optical Science of the University of Arizona to ray trace both a "typical" exoplanet coronagraph system as well as the WFIRST-CGI system. Threshold raw contrast and the field across the complex PSF will be calculated as a function of optical device vector E&M requirements on: 1. Lyot coronagraph mask and stop size, configuration, location and composition, 2. Uniformity of the complex reflectance of the highly reflecting metal mirrors with their dielectric overcoats, and 3. Opto-mechanical layout. Once these requirements are developed polarization aberration mitigation studies can begin to identify a practical solution to compensate polarization errors, not unlike the more developed technology of A/O compensates for pointing and manufacturing errors. Several methods to compensate for chromatic aberration in coronagraphs further compounds the complex PSF errors that require compensation to maximize the best retrieved raw contrast in the presence of exoplanets in the vicinity of stars. Internal instrument polarization introduces partial coherence into the wavefront to distort the speckle-pattern complex-field in the dark hole. An additional factor that determines retrieved raw contrast is our ability to effectively process the polarization-distorted field within the dark hole. This study is essential to the correct calculation of exoplanet coronagraph science yield, development of requirements on subsystem devices (mirrors, stops, masks, spectrometers, wavefront error mitigation optics and opto-mechanical layout) and the development of exoplanet retrieval algorithms.

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Organizational Responsibility

Responsible Mission Directorate:

Science Mission Directorate (SMD)

Responsible Program:

Strategic Astrophysics Technology

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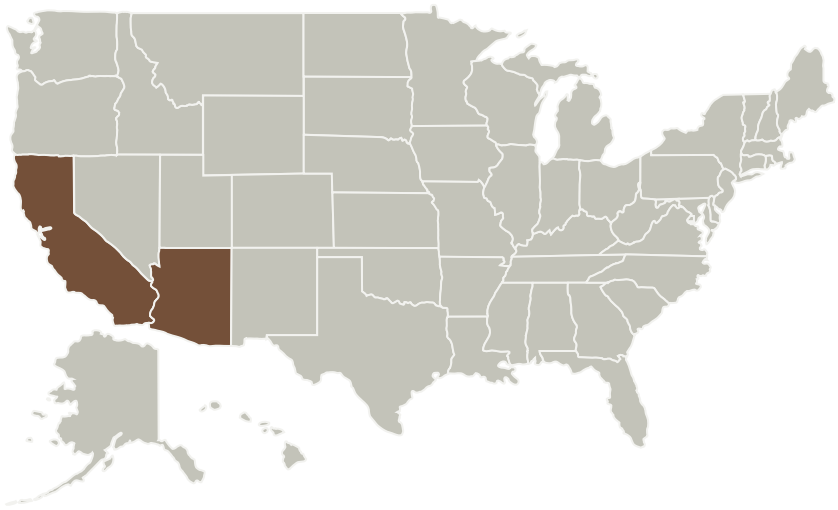
Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
University of Arizona	Supporting Organization	Academia Alaska Native and Native Hawaiian Serving Institutions (ANNH), Hispanic Serving Institutions (HSI)	Tucson, Arizona

Primary U.S. Work Locations	
Arizona	California

Project Management

Program Director:
Mario R Perez

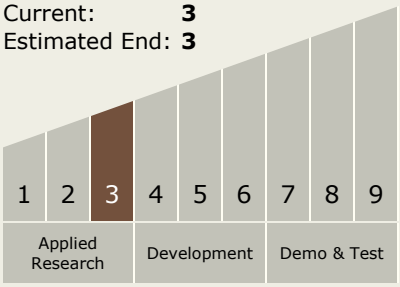
Program Manager:
Mario R Perez

Principal Investigator:
James B Breckinridge

Co-Investigators:
Russell Chipman
Mary Gerrow

Technology Maturity (TRL)

Start: **3**
Current: **3**
Estimated End: **3**



Technology Areas

Primary:

- TX08 Sensors and Instruments
  - TX08.2 Observatories
    - TX08.2.1 Mirror Systems

Target Destination

Outside the Solar System